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ABSTRACT

In response to the challenge for reform in science education, a new graduate course entitled "Advances in Science, Mathematics and Technology Education" was initiated at the University of Massachusetts at Lowell by the College of Education. The course focused specifically on examining how private research and development work dovetails into the stated contemporary goals of the American Association for the Advancement of Science Project 2061. It emphasized the transdisciplinary connections between mathematics, science and technology education. In addition to classes, a series of graduate-level seminars were conducted with nine speakers from private research and development organizations and academic locations outside the College of Education. Other topics covered include the electronic nature of the course, which consisted primarily of a project-centered electronic discussion forum using electronic mail; student-centered objectives; course requirements; and course content, which includes a table of main presentation topics and their corresponding foci. The presentations focused on such course-related themes as habits of the mind in science and mathematics education; breadth versus depth controversy; use of technology in science and mathematics education; and collaboration and connections between teachers, students, researchers, and industry. Project evaluation comprises both formal and informal assessment. (PVD)

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Meeting the Challenge of Professional Development: Design and Evaluation of a Telecommunications Mediated Course in Science, Mathematics and Technology Education

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Introduction and Background

> *Teachers should have opportunities for structured reflection on their teaching practice with colleagues, for collaborative curriculum planning, and for active participation in professional teaching and scientific networks. The challenge of professional development for teachers of science is to create optimal collaborative learning situations in which the best sources of expertise are linked with the experiences and current needs of the teachers (NRC, 1996, p. 58).*

Current reform initiatives in science education have compelled those in higher education to think of new visions for schools. Professional development programs can no longer think of their goals independently from those of other agencies in the broader community. "Schools also are part of communities that contain organizations that influence science education, including colleges and universities, nature centers, parks and museums, businesses, laboratories, community organizations, and various media" (NRC, 1996, p. 8).

To support school reform in America, the American Association for the Advancement of Science (AAAS) has proposed essential steps toward realizing the goals stated in *Science for All Americans* (1989). The first step states: "To ensure the scientific literacy of all students, curricula must be changed to reduce the sheer amount of material covered; to weaken or eliminate rigid subject-matter boundaries; to pay more attention to the connections among science, mathematics, and technology; to present the scientific endeavor as a social enterprise that strongly influences—and is influenced by—human thought and action; and to foster scientific ways of thinking" (p5).

With the introduction of *Curriculum and evaluation standards for school mathematics* (NCTM ,1989), *Professional standards for teaching mathematics* (NCTM, 1991), *Project 2061* (AAAS, 1989),*Benchmarks for Science Literacy,* (AAAS, 1993), *Indicators of Science & Mathematics Education* (NSF, 1996a), *The Learning Curve* (NSF, 1996b), and the *National Science Education Standards* (NRC, 1996), the

ante has been raised in mathematics and science education to implement systemic reform initiatives that are responsive to current demand for a scientifically and technically literate citizenry. While science teachers purportedly align themselves with contemporary goals, formal or informal opportunities for reflection in terms of whether their actual teaching practices are consistent with expressed ideologies are few and remain an open question (Zeidler & Duffy, 1994; Zeidler & Duffy 1995).

Indicators of the importance for reform in science education can be found in recent research. Haney & Lumpe (1996) stress that professional development needs to be guided by a framework that encompasses reform policies, teachers' needs and research. Key components in the proposed framework include the alignment of teacher beliefs with reform goals through conceptual change models, active teaching and learning, intensive long-term training and community and collegial support structures for teachers. Boone & Anderson (1995) have successfully used distance education to deliver activity-based science methods classes. While some "inevitable" technological limitations were noted by the authors, the benefits of providing opportunities for educators to network and collaborate without proximity restrictions far outweighed those problems. Finally, Spector & Phillips (1989) emphasize the necessity of broadening teachers' perspectives on research by demonstrating its relevance to individuals and society in small "think tank", reflective group activities.

What follows is a description of one response to the challenge of reform. A new graduate course entitled *Advances in Science, Mathematics and Technology Education* was a University of Massachusetts Lowell (UML) College of Education initiative partially funded through an internal "Scholarship" grant for course innovation. One goal was to develop course initiatives for the continuous improvement of teaching and learning with respect to professional development. Another goal of the course was to serve as a model for other public institutions in

integrating teaching and learning with Boyer's (1990) other scholarship dimensions (applications, discovery and integration).

In responding to these goals and reform challenges, the present strategy was aimed at bringing fresh perspectives of students, faculty within and outside College of Education, partner scientists from private Research & Development (R&D) organizations and museums into an ongoing discussion on current issues of math, science, technology education and society. The course focused on research and developmental activities in science, math and technology in the context of current reform goals in schools and in higher education. The lead author and head of the Mathematics and Science Education doctoral program in the College of Education designed and taught the course. The second author served as a design consultant for the electronic communications component, and developed significant portions of the successful grant proposal to support the launch of this project.

One aim of this course was to have it complement the existing graduate education program in mathematics and science education by integrating it with private industry resources. The purpose of this deliberate collaboration to gain a wider perspective into current trends in "cutting edge" educational research. Examples of such private and public organizations from the Greater Boston area that cooperated in the delivery of this course were:

- Bolt, Beranek and Newman (BBN)
- Boston Museum of Science
- Educational Development Corporation (EDC)
- Arnold Arboretum

Rationale for Course Design

Recent research and development in science, mathematics and technology education (see above) require examination in light of current reform goals in schools and in higher education. Practicing teachers need the opportunity to reflect,

react and communicate with one another and with individuals in the research community concerning contemporary issues in content and pedagogy. Among these reform issues are the following key elements:

- The union of science and mathematics education with technology can dramatically improve teaching.
- Reform must be comprehensive, involving administrators, faculty, business, school teachers, parents, students and community members.
- Curricula must be changed to weaken rigid subject- matter boundaries.

Related questions posed for the course project are as follows:

- Can school practitioners, university faculty and private sector scientists share a common vision for national reform goals?
- Do the R&D projects currently being developed in the private sector have relevance to national reform movements?
- Do teachers believe the R&D efforts can positively impact their students, teaching practices and curricula?

Course Structure

The course focused specifically on examining how private R&D work dovetails into the stated contemporary goals of the American Association for the Advancement of Science (i.e. Project 2061: Science for All Americans, Benchmarks for Science Literacy). Accordingly, this course had a distinctive Science-Technology-Society (STS) theme. It emphasized the transdiciplinnary connections that STS holds for Mathematics, Science and Technology Education. In addition to classes taught by the first two authors, a series of graduate level seminars were conducted with nine speakers from private R&D organizations and academic locations outside the College of Education (see above).

Electronic Nature of the Course

LeBaron & Bragg (1994) have described the potential for electronic telecommunications in the design and delivery of graduate courses for professional educators. Building on this work, an electronic communication component was woven into the course design. This component consisted primarily of a project-centered electronic discussion forum provided through the facilities of the University's Computer Science Department. After considering a variety of telecommunications options, the course designers settled on a simple, dedicated electronic mail distribution list open only to the major project stakeholders. Electronic mail was selected for the following reasons:

- E-mail is simple to use.
- Many education professionals have access to e-mail.
- E-mail requires minimal technical orientation among members of the user group, thus allowing undiverted concentration on course content.
- E-mail requires minimal computing power, storage capacity and telecommunications speed in order to make effective use of it.
- E-mail was sufficient to the particular communication needs of this course.

Participating students were required to use electronic mail to conduct research and maintain topic-specific dialogues with visiting seminar leaders, UML faculty, and among themselves. Network access was pre-tested from home and school based modems, and from campus based desktops. There appeared to be sufficient access to the UML's Academic Computing Center (ACC) to assure a 90% user "attempt-connect" success rate.

Visiting seminar leaders were paid modest stipends for their contribution to the intellectual vitality of this project, and asked to serve as "electronic advisors in residence" throughout the semester. Through the electronic discussion forum, these leaders interacted with students, faculty and with each other. Throughout the

course, a trained teaching assistant was hired to coordinate and moderate these "electronic conversations".

All electronic interactions and discussions were moderated in order to maintain a sense of conversational purpose, and to assure adherence to acceptable academic standards. For example, it was the moderator's job to monitor group communication and note messages that were deemed offensive, off track or inappropriate. Such messages were sent back to the sender with a request for revision, and suggestions for more careful future postings.

Student-Centered Objectives

Doctoral students enrolled in this course to fulfill their graduate requirements. Additionally, potential graduate students from regional school systems and educational organizations registered to fulfill their inservice professional certification requirements or for their own professional growth. The majority of this latter group were teachers of mathematics, science or technology.

Student enrollees could select a one-credit (six sessions) or a three-credit option. The one-credit option was given particularly to school personnel needing to augment their professional development portfolios for the new teacher re-certification requirements included in the State's 1993 Educational Reform Act. The three-credit option fulfilled the graduate requirements of fully-matriculated students.

As a result of their participation students were expected to:

- Demonstrate comprehension of contemporary recommendations and goals of AAAS for science education reform.
- Evaluate the efficacy of goals by AAAS with respect to their areas of classroom teaching and local school systems.

- Develop a personal model of scientific literacy that reflects the nature of science, mathematics, and technology, and the interactions of these areas with society.
- Correlate current research and development topics with the proposed AAAS reform goals, and with respect to their areas of teaching.
- Gain experience with electronic forms of network dialogue and communication.
- Participate in a "community of scholars" as they interacted (in person and via electronic forums) with researchers for R&D organizations, other faculty members, and each other.
- Contribute to the assessment of this course/project.
- Establish informal relations with private R&D organizations for the possibility of future collaboration initiatives.

Course Requirements

One of the objectives of the course pertained to how works of educational R&D organizations were consistent with the stated contemporary goals of American Association for the Advancement of Science. Therefore, students were asked to read Project 2061: Science for all Americans and Benchmarks for Science Literacy since these books were aligned with the objective of the course. Students attended fifteen class meetings and presentations. Additionally, students wrote a summary reflective-reaction paper and maintained electronic dialogue on topic-specific areas with visiting speaker leaders, UML faculty, and among themselves. Furthermore, students were required to examine the process of program develop and the outcomes of the course using a formative and summative evaluation component. The students accomplished this following Smith's (1989) "Evaluability Assessment" model as part of their writing assignment.

Course Content

The speakers represented various perspectives on topics not normally encountered by students formally enrolled in graduate education courses at universities. The presentations focused on such course-related themes as:

- habits of the mind in science and mathematics education
- breadth verses depth controversy
- use of technology in science and mathematics education
- collaboration and connections among teachers, students, researchers and industry.

The seminar leaders also emphasized that, in order to make math and science more meaningful to students, interdisciplinary work should be encouraged in schools. Examples of such integration are found in Figure 1 which lists the main topics and their corresponding foci.

[Please See Figure 1 on Next Page]

Figure 1.

Topic: Nuclear Engineering, Values, and Decision Making;
Focus: The importance of producing scientifically literate citizens able to understand and debate issues of morals, economics and technology.
Topic: Creative Contraptions: Computer Assisted Lego/Logo Projects for Students.
Focus: Constructivist approach to teach scientific and mathematical concepts by taking a "product" in a microworld through various stages of development.
Topic: Seeing Beauty in Mathematics and Related Projects: Visual and Experimental Approaches to Mathematics.
Focus: Real world problems, cooperative learning, visualization strategies and nurturing the affective experiences of students.
Topic: A World in Motion: The Design Experience (Promoting Women in Science, Math and Technology).
Focus: The impact of industry and business on educational materials development and interdisciplinary engineering-design topics for middle school.
Topic: School - Teachers, Time and Transformations (Business Partnerships/ Industry Volunteers in the Classroom and Enrichment for Teachers.
Focus: Discovering the benefits of having release time sponsored by industries for teachers to become reflective practitioners thereby increasing their "comfort zone" in the activities of science.
Topic: Connected Geometry: Activities That Explore Unifying Themes in Mathematics and Connect Them to Past Experiences.
Focus: "Meaningful" mathematics (any content) conveyed by real world problems and developing habits of mind the value through aesthetic experiences.
Topic: The Role of Software in Conceptual Change of Scientific Misconceptions.
Focus: Creating cognitive dissonance with anomalous data - providing high school students with an opportunity for modeling and simulation experimentation
Topic: The Role of Fallacious Reasoning in Teaching Science.
Focus: Debate and argumentation used as useful tools in advancing understanding of social-scientific dilemmas and common flaws in argumentative reasoning.
Topic: The Living Museum: Botanical Garden Projects with Schools.
Focus: Hands-on experiences and distance learning as a gateway for systemic change.
Topic: Mathematical Misconceptions, Conceptual Change and Software.
Focus: Challenging the assumption that algebra needs to be a prerequisite for calculus and examines alternatives to using algebra as a social and economic separator for students.

All presenters were provided with background information on the students and were informed that "on-line" discussions the week following their presentation would ensue. It was expected that each speaker would also contribute to that electronic discussion. In addition, each seminar leader was asked to post a propositional statement for the electronic bulletin board designed to elicit peer response among students and faculty. The statement was conceptually related to the presentation and could be worded as a proposition, an argument, a position, a

"request for comment" or some other form of discourse. (Each new week brought a new speaker, a new topic and a new set of on-line discussions.)

In addition to the guest speakers discussing their own research, they responded to questions concerning how the research was funded, and relevance of their research to schools and industry. All guest presentations were illustrated with a variety of interactive computer applications. The presenters provided "hands-on/minds on" practice with computer software packages, manipulatives or local field work. Further, they addressed the need for schools to engender problem-solving habits of mind, such as experimenting, looking for patterns, algorithmic thinking, reasoning for continuity, and using linearity and calculating.

Project Evaluation

Project evaluation provides an opportunity for the staff and participants to assess or re-evaluate its priorities and structure. Based on the premise that instructional excellence and innovation applies equally to graduate education as to public school teaching, this pilot project was targeted directly at the College's own practices in a manner that informed its faculty, as well as serving as a model for other similar university or public school initiatives. In a very strict sense, the faculty were co-learners with the students. They fully participated in all learning experiences. The nature and quality of these learning experiences were continually assessed with respect to the course and institutional objectives. Hence, a series of informal and formal evaluations were built into this project .

Informal Assessment:

Informal ongoing monitoring and assessment of project activities was conducted, which included dialogue about the nature of scholarship, particularly its relationship to faculty evaluation and performance assessment. Partner scientists were asked to share their perceptions about this incipient partnership with a view to more in-depth future collaborations. In addition to the routine assessment of

student outcomes, student perceptions about this project were also assessed in much the same way as were the visiting seminar leaders. These perceptions of the program were evaluated through a standard evaluation form which featured four open-ended questions applicable both to guest speakers and the students.

The seminar series form that students used to evaluate guest speakers included open-ended questions designed to discover what students liked or disliked about the speaker, the discussion topics, and what suggestions they had for speakers and instructors to consider in future. The evaluation form given to the speakers to evaluate their participation included questions asking what they liked or disliked about the experience at the University, and what suggestions they had for students or course instructors to consider for the future. The scores on the seminar series reported by the students on the speakers were very positive ranging from 7.3 to 9.3 out of a possible 10. Below are some representative perceptions that students wrote about the speakers:

- Speakers were confident, engaging, knowledgeable, informative and well connected to the student perspective of the learning process.
- Speakers used computer software technology effectively.
- Speakers presented a balance between discussion and hands-on activities.
- Speakers provided valuable insights to teachers on how to obtain and use effective teaching materials.

The scores reported by the guest speakers on the students were similarly positive ranging from 8 - 10 out of a possible 10. Below, are some of the perceptions that guest speakers had of students at the College of Education.

- Speakers found course participants to be very enthusiastic and insightful. They asked challenging questions that encouraged speakers to rethink their own views of learning.

- Speakers found e-mail discussion lively and helpful in preparing for and following up on their presentations.
- Speakers felt that the model should be continued and be disseminated to other universities for replication or adaptation.
- Speakers were pleased with the organization of the course and the well equipped facilities that optimized the effectiveness of their presentations.

Formal Assessment: The Evaluability Model:

A more structured form of assessment was conducted in a manner consistent with the Evaluability Assessment (EA) Model of Smith (1989). There are two main features of the EA approach that provide the context in which an analysis of a program is possible. First, a definition(s) of the program's theory; determining and assessing the underlying logic (relationships among variables) and functional aspects (administrative and logistical considerations) is ascertained. Evidence of intended and unintended outcomes is sought. Second, identification of the stakeholder's interest, awareness, and perceptions, and concerns related to the program is sought through direct observations, structured and semi-structured interviews, surveys, and document reviews.

These features provide the basis to describe and clarify a program's theory, identify possible intervening variables for the continuation of a program, examine the plausibility and feasibility of reaching projected program goals, and suggest recommendations for how to use the information obtained from the evaluation. It should be emphasized that this approach allows for competing or alternative perceptions to be utilized in formulating a model of a program's theory.

The framework of our approach is described in ten (10) steps below. It should be emphasized that the means to implement some of these steps is at times quantitative in nature, qualitative in nature, analytic in nature, or some combination thereof. It is, however, a model that favors formative and qualitative

evaluation allowing for multiple perspectives. Hence, the model described below must necessarily be generic to best capture how the program proceeds at a given point in time. Guiding foci for the major steps are provided with a description of each step as it pertains to the present project appearing parenthetically. These foci were understood to be tentative in nature because of the developmental nature of the project. The recursive nature of the evaluation in terms of developing the program theory model is implicit in the following discrete steps and is represented by Figure 2.

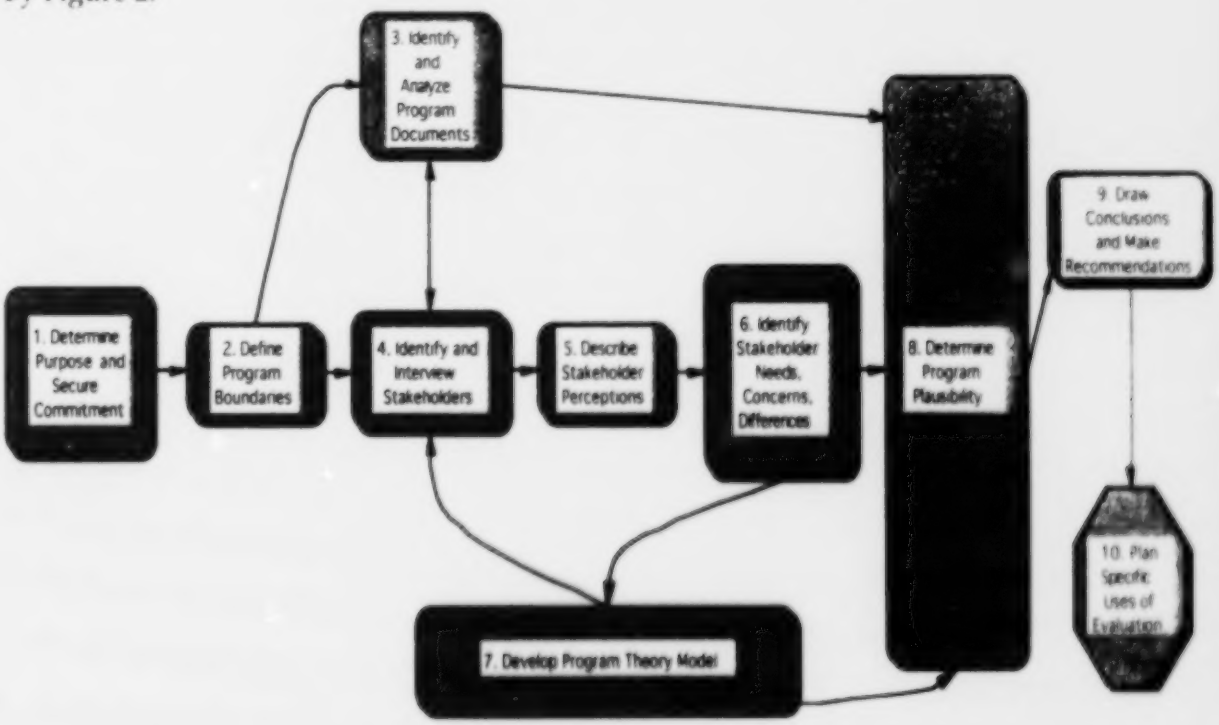
3. Identify and Analyze Program Documents
9. Draw Conclusions and Make Recommendations
1. Determine Purpose and Secure Commitment
2. Define Program Boundaries
4. Identify and Interview Stakeholders
5. Describe Stakeholder Perceptions
6. Identify Stakeholder Needs, Concerns, Differences
8. Determine Program Plausibility
10. Plan Specific Uses of Evaluation
7. Develop Program Theory Model

Figure 2. Evaluability Assessment Model (Adapted from Smith, 1989)

1) Determine Purpose, Secure Commitment. Meet with primary stakeholder(s) (administrators, private corporations, researchers, potential students) to explain the proposed EA-Qualitative Evaluation. Purposes are clarified and generally agreed upon, and administrative support secured. Additional individuals who may

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provide input at this early stage are sought to help delimit the breadth of the evaluation context. (Key personnel from EDC, BBN, Boston Museum of Science, Arnold Arboretum, Faculty from the College of Education, Chair, College of Education, Graduate Students from Mathematics & Science Education Doctoral Program were contacted and the nature of the proposed course discussed.)

2) Define Boundaries of Program to be Evaluated. A continuation of (1) above, program boundaries are further delimited or defined in terms of geographical areas, broad based goals, site specific goals, services provided, clients served or some combinations of these. A secondary analysis of the priority of various goals among and within different sites is ascertained and compared and contrasted among sites. (Discussed objectives of Scholarship innovation grant with administration, sought input from other Departments and Centers, developed course syllabus, met several times with graduate students to identify specific topics and researchers related to interests and needs.)

3) Identify and Analyze Program Documents. Program documents are collected including publicity brochures and press releases, in addition to internal documents, reports, and evaluations. An effort is made to distinguish between political and social realities of various stakeholders. Finally, an analysis is made with regard to the information flow of important materials or concerns. (This included internal documents of Scholarship Committee, *AAAS Project 2061 & Benchmarks Reports;* EDC and BBN Annual Reports, among others.)

4) Identify and Interview Stakeholders. Interviews are conducted (whether in person or by survey) of those who directly administer, implement, or participate in this program, including those that may have vested interest in this initiative. Information is gathered by appropriate quantitative or qualitative means (e.g. direct observation, structured and semi-structured interviews, survey research, and document reviews).

5) Describe Stakeholder Perceptions of Program. The evaluation formulates initial categories and clusters which represent common concerns among those individuals who have been interviewed. Categories are tentative and are subject to modification so that major themes may be adequately described that best capture the major goals/concerns. (Guiding themes for the seminar series were developed by students according to their professional development needs. These themes led to four major clusters of questions to be addressed by various speakers; the major themes included: 1) Origin of a project/Idea; 2) Evaluation, Field Testing and Training of Projects; 3) Pedagogical Concerns; 4) Personal Motivation (for School-based R&D Projects)

6) Identify Stakeholder Needs, Concerns, and Differences in Perceptions. This step involves fleshing out the categories and beginning to see if causal and theoretical statements can emerge form the data. This "fine tuning" of qualitative categories is aimed at discovering if a common program model is shared among all program administrators, personnel, instructors, and participants, or whether multiple realities (conceptualizations) are present. (Comparisons were made among individuals involved at all program levels and the program documentation. Expectations among individuals were compared to ascertain if they converge or diverge, if they were realistic or unrealistic.)

7) Develop and Clarify Program Theory Model. In practice, the development of the program theory model is a recursive process that subsumes steps (4), (5), and (6) in the evaluation process. Various administrators, staff, and participants are asked to offer their views as to how this program is supposed to work, their perceptions of the enabling factors that allow it to function well, and their beliefs as to the impediments that may cause the intended outcomes to fall short of their mark. An overriding goal of this aspect of the evaluation is to identify multiple indicators that suggest a logical sequence of program activities (or lack thereof) and respective

effects for participants. (Graduate students and the program faculty were interviewed to see if a rational basis existed among those involved for believing that particular outcomes were likely to occur given the program strategies. These assumptions could be explicit or implicit in nature. The working assumptions of the actual program were compared with those intended by those who conceived various initiatives. External criteria such as AAAS Goals and internal criteria such as institutional objectives were utilized. Steps 4, 5 and 6 also included input from seminar discussants).

8) Determine Plausibility of Program Model. The likelihood that the program (or parts of the program) will have (or had) the intended effect(s) is addressed. Evidence is sought to demonstrate which factors (goals, premises, activities, resources) are necessary and sufficient for the initiative to succeed. (Institutional resources, logistical considerations, flow of technological information, and drawing from information from steps above were considered collectively to determine the efficacy of the program.)

9) Draw Conclusions and Make Recommendations. Description based on the qualitative inquiries, analytic reviews, and supporting quantitative information lead to an interpretative analysis with respect to the intended goals of this initiative. The basis on which particular conclusions are formulated are made clear. By providing this information, outsiders may determine the degree to which the particular conclusions are warranted. (Summative and concluding statements were formulated with exemplars, or rationales indicating why particular conclusions are warranted.)

10) Plan Specific Steps for Utilization of Evaluation. The evaluators meet with key personnel to determine how the evaluation may be used to make desirable changes in the existing program, or identify what may need to be done to meet new demands or move in new directions. (Recommendations based on the College of

Education's experiences for dissemination to other similar programs, institutions or settings were made.)

The synthesis of the formal evaluation led to beneficial pedagogical outcomes that serve to enhance the professional development of science and mathematics teachers. In summary, seminar participants found this course to have been unique and valuable in comparison to other courses that are offered at the University. Particular course benefits were cited; these included:

a.) Closer University ties to the private R&D community in the greater Boston area. Students also established informal and continuing relations with the participating R&D organizations.

b.) Better service to current graduate students. The presenters extensively used electronic communications capacities for program-related instructions and academic support.

c.) Improved interdisciplinary work within the University. Collaborative ties with other colleges and departments were initiated.

d.) Enhanced use of educational technology. Students learned to use electronic communication and novel technological capabilities for conducting research, gain access to Internet, and have an on-going dialogue with speakers and among themselves. A "community of learners" was established through personal interaction at seminars and electronic forums. This "community" exchanged fresh perspectives about math, science, and technology education by linking academic theory to "real world" applications.

e.) Intensified diffusion of learned practices. Electronic communication encouraged the production of "mini papers" based on student research of the posted questions and problems.

On the other hand, participants recommended the following changes for the future improvement of the course:

a.) There had been occasional obstacles to using the electronic forum due to the down-time of University network.

b.) Participation from educators outside the College of Education was low.

As described above, much narrative data from interviews was collected, too voluminous to present here. But a "sampling of thought" revealed in the following two students' remarks may serve as a reality check to the professional development concerns of our ultimate consumers - our students!

"Today, institutions are seeing that an integrated approach to the establishment of collaboration and partnerships with private companies conducting scientific and technology research, can increase their ability to attract graduate students and research funding. . . . This integrated strategy should look at such issues as institutional mission, position in the marketplace and good student-institution-company matches in maintaining and improving relationships. These functions must be part of the development and implementation of an effective science, mathematics and technology educational program."

"The College of Education must be committed to the concept of collaboration and the establishment of partnerships with other institutions and private companies. Putting the pieces together is the responsibility of every representative of the institution, administrators, faculty, graduate student, and other staff members. These are the individuals that make a positive or negative contribution to the institution's ability to implement an effective collaboration and partnership program for science, mathematics and technology education."

Conclusion and Implications

The National Council for the Accreditation of Teacher Education (NCATE) and most states require that students in teacher preparation programs take technology courses for teacher certification and recommend that such programs integrate the use of technology into their courses of study. This course and initiatives like it would contribute towards obtaining professional development points for recertification and/or credit.

An issue may arise as to the transferability of the ideas contained in the rationale for this course to other science and mathematics teacher education programs. The authors contend that future iterations of this course hold promise both for the clinical preparation of teachers and advanced graduate seminars in teacher education: ". . . it is possible to develop an extremely robust activity system for the clinical preparation of teachers that is mediated by technology be configuring tools already available to teacher preparation with telecommunication. E-mail, computer mediated conferences, and video conferencing are tools especially suited for constituting social arrangements that enable students to jointly construct knowledge about teaching ... Discourse of this kind becomes a tool for reflection and the creation and restructuring of knowledge about teaching" (Blanton, 1993).

The objectives and outcomes built into this course structure are also consistent with Gresham's (1994) notion of an "invisible college" which consists of a social network of people with who operate as a scholarly group within a given specialization through an array of electronic forums or electronic journals. "...informal communication networks provide a forum for the sharing and testing of new ideas through feedback and discussion. Inter-disciplinary exchange of ideas emerges along the peripheries of inter-connecting invisible colleges ... Due to publication lags in the formal scholarly communication networks, the cutting edge

of information in a given scholarly specialization is frequently found within these invisible colleges" (Gresham, 1994).

The course, *Advances in Science, Mathematics and Technology Education,* fundamentally strengthened the organizational partnership between the University and the private R&D community in the greater Boston region. In addition, it set an example for other higher educational institutions to seek and secure private sector participation in their professional programs. The course brought fresh perspectives to the academic lives of the participants, especially the students. Finally, the judicious use of computer based networking woven into the course design expanded the scope and quality of intellectual "conversation", encouraged peer-problem solving and provided instructional support that traditional methods cannot easily provide.

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